Attachment B

Text Revisions / Reorganizations
(As of July 11, 2002)

CHAPTER 2
CAPABILITIES REQUIRED FOR AN LTS SYSTEM

2.1 INTRODUCTION

As explained in Chapter 1, the equation S = (MC)2 is meant as an easily remembered shorthand for an overarching principle that emerged from the efforts of the roadmap team to identify the essential, highest priority capabilities needed for a DOE site entering long-term stewardship:

> Long-term stewardship of a site with residual contamination must be viewed as a system. The essential functions this system must perform are to ***contain*** the residual contaminants, ***monitor*** the site and the LTS system, ***communicate*** within and beyond the LTS system, and ***manage*** the system.

2.1.1 LTS System Capabilities

The roadmap team first identified 88 stewardship capabilities that meet both of the following conditions.

1. The capability has a substantive S&T component.
2. DOE closure sites either lack the capability but need it to meet regulatory or statutory requirements or potential improvements in the capability, technically feasible by 2008, would substantially reduce risks to human health or the environment, reduce life cycle stewardship costs, or decrease technical uncertainties. In the first case, the capability fills an unmet need of site stewardship. In the second, the capability substantially increases effectiveness and efficiency in the long term.

Over the course of five months and two additional workshop meetings, this starting set of capabilities was trimmed and redefined to ten capabilities essential for a long-term functioning stewardship system. These ten ***system capabilities*** are the objectives to be reached by the S&T Roadmap. The roadmap team defined specific targets to be achieved by 2008 for the system capabilities. In some cases, there was a single S&T target for the entire system capability. In most cases, however, S&T targets were defined for two or more aspects of the system capability.

In this chapter, each system capability is discussed under the LTS core function (Contain, Monitor, Communicate, or Manage) to which it is most relevant. However, all the system capabilities have some connection with at least two of the core functions, and some capabilities are important to all four functions. For example, although System Capability 8, LTS system performance validation and monitoring, is discussed under the Management function, it is obviously important to all four core functions.

Table 2-1 lists the entire capability structure used by the LTS roadmap. System capabilities are identified by a whole number from 1 to 10 (for example, System Capability 8). If S&T targets are defined for several aspects of a system capability, each aspect is identified with a decimal number. For example, there are targets for five aspects of System Capability 8, identified as Capability 8.1 through 8.5.

The objectives of this chapter are (1) to explain why each system capability is essential to long-term stewardship understood as a system and (2) to show what each S&T target will add to these capabilities. Chapter 3 presents the R&D pathways developed by the roadmap team to achieve the S&T targets by 2008.

2.1.1 The Concept of Failure in Long-Term System Performance

A major system-level objective for long-term stewardship is to reduce the potential for future undesirable events. If the stewardship system has been designed and operated to prevent an undesirable event, but the event occurs anyway, a *system failure*, in a sense, has occurred. However, this system failure may not mean that any particular component of the system failed, particularly in the sense of a physical failure or "break-down." Likewise, a component failure (for example, a physical failure of a containment unit or a physical access control) may not (and should not) lead to a catastrophic system failure. The system should be designed for defense in depth that eliminates as many "single-point failure modes" in subsystems and the entire system as possible.

Thus, in any discussion of "failure," one must be careful to specify the intended sense of the term. "Failure" is often used in the literature to indicate an "undesirable event" that may or may not equate to a physical failure of containment, etc. In the material that follows, the roadmap team uses the term "failure" to indicate the occurrence of an undesirable event that may lead to actual failure with the passage of time. Clearly, the goal for the stewardship system is to define and monitor *indicators of potential failure* so that the site steward(s) can intervene effectively to prevent any catastrophic system failure from occurring.

2.1.2 The LTS Technology Store

Every DOE closure site that is transferred into long-term stewardship because of residual contamination on site will require the four core functions of containing, monitoring, communicating, and managing. Yet each site has unique characteristics, and the stewardship system will have to be tailored to meet them. For this reason, many of the S&T solutions and improvements in the roadmap were formulated to provide options and tools for the planners and managers of stewardship for individual sites. The roadmap team adopted the name ***LTS Technology Store*** for this collection of tools and options for designing, installing, maintaining, and improving a site-specific stewardship system.

The idea behind a LTS Technology Store is that science and technology do not dictate specific solutions for site stewardship. Nor is one technology the best choice, or even an appropriate choice, for every site. The products of the research and development pathways presented in Chapter 3 will broaden and strengthen the choices available for

TABLE 2-1 Capabilities Necessary for a Site-Specific Long-Term Stewardship System

CONTAIN Residual Contaminants

- System Capability 1. Site Contaminants and Conceptual Modeling Tools for the LTS Technology Store
  - Capability 1.1. Tools for long-term forecasting of environmental settings relevant to predicted end states
  - Capability 1.1. GHBCT conceptual modeling to improve long-term forecasting
  - Capability 1.3. Tools for modeling the community at risk
- System Capability 2. Deploy Alternative CC&C Systems
  - Capability 2.1 Engineer the thermobiogeochemical environment to limit contaminant toxicity and mobility
  - Capability 2.2. Design, build, and operate alternative (next-generation) containment systems
- System Capability 3. Conceptualize and Predict Containment/Control System Performance, Potential Failure Modes, and Levels of Failure

MONITOR the Site and the LTS System

- System Capability 4. Selection of Sensors and Sensor Systems for Site Monitoring
  - Capability 4.1. Sensors and sensor systems for contaminant monitoring
  - Capability 4.2. Sensors and sensor systems for monitoring active and passive safety systems
- System Capability 5. Identify Multimedia Monitoring Needs and Fill Sensor Technology Gaps to Meet Those Needs
  - Capability 5.1. Establish criteria for health exposure for occupational and non-occupational (community at risk) routes of exposure
  - Capability 5.2. Identify contaminant monitoring needs for all media of potential transport or exposure and fill sensor technology gaps where monitoring solutions are needed

COMMUNICATE Within and Beyond the LTS System

- System Capability 6. Collection, Assimilation, Visualization, Evaluation, Dissemination, and Management of Information about the Site
  - Capability 6.1. Integrated information visualization and display system
  - Capability 6.2. Performance data communication module
  - Capability 6.3. LTS Technology Store options for intergenerational information archiving
- System Capability 7. Establish and Maintain Site–Community Communications
  - Capability 7.1. Involve the community in the conduct of site stewardship
  - Capability 7.2. Learn what affects public trust and confidence
  - Capability 7.3. Identify and solve problems that can undermine reliability and consistency in LTS institutions

MANAGE the LTS System

- System Capability 8. LTS System Performance Validation and Monitoring
  - Capability 8.1. LTS Technology Store options for techniques and technologies to improve planning, design, implementation, and decision-support capabilities of CC&C systems and their associated monitoring systems
  - Capability 8.2. Validate performance of CC&C and monitoring subsystems
  - Capability 8.3. Validate overall (technical and nontechnical) performance of safety systems and land-use controls
  - Capability 8.4. System performance module for collection, analysis, evaluation, and dissemination of data
  - Capability 8.5. Periodically revisit cleanup/stewardship decisions to ensure continuous improvement
- System Capability 9. Land-Use Controls and Their Survivability
  - Capability 9.1. Legal pathway modules to identify potential legal strategies, assess established agreements, and develop draft alternative legal instruments
  - Capability 9.2. Intergenerational archive options for maintaining land-use control information
- System Capability 10. Integration of Preventive Maintenance Requirements into Site Subsystems

efficient and effective stewardship, rather than forcing standardized, one-size-fits-all responses to complex conditions and issues.

[RK1]) To use the LTS Technology Store, a stewardship planner or manager would begin with characterization data on the site's residual contamination and site features that influence transport of contaminants by air, surface transport (biotransport, surface water, etc.), or subsurface transport (Capabilities 1.1 and 1.2). Software modules provided in the Technology Store would use this information to determine the appropriate target contaminants, surrogates, and performance indicators for monitoring subsystems (Capabilities 4.1, 5.2, and 8.1). These modules would also incorporate information on the community at risk (Capability 1.3) and health exposure criteria for both occupational and non-occupational routes of exposure (Capability 5.1). Other software modules available in the Technology Store help the planner/manager select the passive and active access controls needed for a defense-in-depth strategy at the site (Capabilities 8.3 and 9.1). The results from these steps would feed into another software module, which provides suggestions on design of monitoring subsystems for contaminant monitoring and access control appropriate to the containment systems and hazards on the site (Capabilities 8.1 through 8.4). After monitoring and access control subsystems are designed and implemented, the site steward would continue to use tools from the LTS Technology Store for validating system performance, maintaining essential information for the long term, and periodically re-evaluating the technical and nontechnical components of the overall LTS system (System Capability 8).

The benefits to the LTS planner or manager of a "technology store" of options and a methodology for selecting and tailoring them can be measured in terms of increased cost effectiveness, lower maintenance costs, reduced occupational exposure, and increased safety and reliability for both the community and the steward. LTS planners and managers for a site can reduce life cycle costs (as well as capital cost), technical uncertainty, and health and environmental risks across multiple sites if they have the tools for selecting and tailoring systems to meet site-specific requirements. The LTS Technology Store will provide them with a set of generic, proven, risk-based, efficient systems and a methodology for tailoring these generic systems and selecting the best options for a particular site.

2.2 CONTAIN RESIDUAL CONTAMINANTS

2.2.1 System Capability 1. Site Contaminants and Conceptual Modeling Tools for the LTS Technology Store

Understanding the interactions among site contaminants and the site-specific environment is essential to designing and planning for a stewardship system that will remain efficient and effective over time. Conceptual models are the basis for this understanding. Good conceptual models are essential for designing and implementing contamination containment and control (CC&C) systems, the systems for monitoring the CC&C systems, and the physical systems for site access control and access monitoring. All of these technology-based systems must be designed, implemented, and operated as subsystems of the total stewardship system. Adequate conceptual models for the site are the foundation for this integration.

The roadmap team identified three aspects of System Capability 1 in which substantial improvements can be made by 2008, resulting in products available to LTS planners and managers through the LTS Technology Store.

1. Models that characterize site environmental settings and predicted end states well enough to enable design and implementation of CC&C systems that can be effectively monitored and maintained over the extended periods envisioned for LTS.
2. Conceptual models incorporating the best available scientific understanding of the complex, interacting geologic-hydrologic-biological-chemical-thermal (GHBCT) processes that control contaminant fate and transport.
3. A tool for modeling the community at risk from residual contamination at the site. The community at risk is the population that could credibly be exposed to any residual contaminants moving by airborne or other surface transportation routes.

An S&T target was defined for each of these subcapabilities contributing to System Capability 1. Each capability area is described in more detail below, ending with its S&T target for 2008. The pathways to achieve the targets are in Chapter 3.

Capability 1.1.[RK2] **Tools for long-term forecasting of environmental settings relevant to predicted end states**

This capability for the LTS Technology Store will allow LTS planners and managers to characterize current environmental settings and predicted end states well enough to design and implement CC&C systems that can be effectively and efficiently monitored and maintained over long periods. An understanding of the current and projected environmental states at each stewardship site is needed to identify reasonable ranges for long-term changes that could lead to failure of CC&C systems over time. These conditions fall into five major categories: (1) climate change; (2) ecological succession; (3) pedogenesis (including soil structure and horizon development, bioturbation, desiccation, and freeze-thaw cracking); (4) landform processes (such as erosion networks resulting in topographic changes); and (5) land use, with primary emphasis on the next few generations. Also essential to this characterization is an understanding of how site contaminants behave in these settings.

The modeling capability to be provided with this LTS Technology Store tool would support characterization of:

1. Transformation and attenuation processes (to more or less toxic forms, including radioactive decay, biodegradation, hydrolysis, and photolysis)
2. Mobility (including sorption, fixation, and complexation)
3. Bioavailability, also considering uptake, transfer, and other partitioning factors.

2008 Target for Capability 1.1: Develop characterization technologies and analytical tools for the LTS Technology Store that enable long term forecasting of system performance.

Capability 1.2 GHBCT conceptual modeling to improve long-term forecasting

The conceptual model for a site is an essential tool on which one can base the site-wide risk assessment and the design of the site remediation and stewardship plan, as well as the design of the site monitoring system. The conceptual model also defines which contaminants and GHBCT parameters need to be modeled.

Site conceptual models for contaminant fate and transport are the basis for selecting the numerical models and analytic approaches used to design and predict performance of a remediation plan for the site. Output from the predictive numerical models, run with input data from the site monitoring system, is essential for updating the site performance assessment. The updated results from the performance assessment feed back into review and refinement of the data needed from the monitoring system. In turn, the conceptual models and this iterative predictive modeling define how the monitoring system will trigger contingency plans in the event of a contaminant release from containment.

The roadmap team forecast that improvements in GHBCT modeling would have a high impact on reducing technical uncertainty, since a better conceptual model provides better estimates of source terms, release rates, barrier failure mechanisms, and contaminant fate and transport. The impacts on reducing cost and reducing risks were estimated to be high because the conceptual model is fundamental to many other monitoring and CC&C techniques for reducing cost (see, for example, System Capability 2).

2008 Target for Capability 1.2: Sites have the capability, provided through the LTS Technology Store, to adapt the site monitoring system based on improvements to the GHBCT conceptual model for the site.

Capability 1.3. Tools for modeling the community at risk

Another set of tools for the LTS Technology Store is needed to enable planning and managing LTS with respect to the community at risk. Conceptually, the community at risk is defined by the areas in which populations live, recreate, or visit that are adjacent to areas of the site where contaminants are contained and access is controlled (i.e., the access control boundaries). Credible and defensible estimates of the extent and scope of the community at risk require four contributing estimations:

1. Characterization of the source term of residual contaminants and the determination of contaminant and surrogate species as targets for monitoring.
2. Reliability of detecting the monitoring targets
3. Meteorological conditions
4. Demographic conditions, i.e., the type of use in adjacent areas.

To be adequate for long-term stewardship, a model for the community at risk must diverge in an important way from many current modeling approaches. The LTS model must assume that the site boundaries will not remain static over time, given existing land-use controls. For example, zoning ordinances may only last as long as two or three changes in county administration. (System Capability 9 addresses issues related to developing more effective, survivable land-use controls.)

One module of the model will require input about the nearby or resident human populations, visitors to the site or adjacent off-site areas, etc. Another module provides a defensible, credible technical framework for identifying the community at risk at any specified time in the LTS evolution. This framework should be based on a peer-reviewed methodology that can be tailored to the specific characteristics of a site.

A close analogy to the methodology required for the framework module exists in the 29 CFR regulations recently passed by the U.S. Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA) for process safety at chemical plants that use large quantities of highly hazardous chemicals. These regulations require identification of source terms by quantity and characteristics, downwind vapor hazards, and other relevant factors. As a benchmark for the effort required to develop a legally defensible and socially credible framework module, these process safety regulations took years and many hundreds of thousands of dollars to draft and finally promulgate as federal regulations.

Many large municipal governments already require a sampling strategy for the surrounding community from contractors that are remediating urban waste sites to "brownfield" status. The remediation contractor is required to determine the zone of influence on the surrounding community, which is roughly equivalent to what is defined here as the "community at risk." Thus, there are practical precedents on which to build a modeling capability.

2008 Target for Capability 1.3: Develop modeling modules for the LTS Technology Store for estimating the community at risk for a LTS site.

2.2.2 System Capability 2. Deploy Alternative CC&C Systems

Virtually every DOE stewardship site will require long-term isolation of contaminants in vaults, disposal cells, waste tanks, or other units. To be successful, many of these containment systems may need to control contaminant migration for hundreds to thousands of years. During this extended control period, natural processes will tend to breach the containments and mobilize the contaminants. The engineering challenge posed by this need for effective long-term containment is unprecedented and daunting**.** Current design approaches typically fail to account for inevitable changes over the long term in the environmental setting of containment units.

Most DOE sites also have environmental contamination—in surface soils and sediment, in the vadose zone, or in groundwater—that will remain in place after the planned remediation programs conclude. For example, DOE recently estimated that there are 176 groundwater plumes across the DOE complex.[RK3] Long-term programs of pumping and treating groundwater, including extensive active interventions during an extended period of stewardship, continue to be the default controlling technology for most of these plumes. Also, the plan or expectation at several DOE sites is that runoff or subsurface water from contaminated locations (for example, sites of former French drains) will continue to be collected for ex situ treatment. These collection and treatment systems must operate effectively far into the future. Management of (potentially) contaminated water will be an enormous burden for site stewards unless alternative technologies are deployed to reduce the volumes of water requiring active management. Successful implementation of alternative technologies could yield huge savings, depending on the life cycle cost of the technology implemented. Just as important, alternatives that could contain and control the residual contamination by means other than collecting and treating water contaminated at low concentrations could reduce health and environmental risks, if they increase long-term reliability of the system by reducing susceptibility to lapses in operation and maintenance. (See System Capability 10.)

Existing containment design approaches rely on conventional engineering methods that fail to incorporate key aspects of environmental change. Typical designs are collections of prescribed physical barriers to known or perceived release pathways; rarely have they been evaluated as integrated systems. The limited field evaluations available to date show that many existing containment and cover designs are already failing to meet performance standards. In particular, natural forces such as biointrusion, desiccation, frost penetration, and other soil development processes increase the permeability not just of compacted soil layers but even of resistive materials that were intended to remain impermeable for decades.

No known designs can withstand these natural forces for hundreds of years. Many systems currently deployed or being planned rely on continuous maintenance or other active interventions (such as water treatment). Other approaches require periodic replacement to continue functioning as intended.

System Capability 2 will allow site stewards to deploy alternative contamination containment and control systems that will function effectively over the long term with a significantly reduced degree of intervention (including maintenance, monitoring, and institutional control). To accommodate long-term environmental change, these alternatives would integrate and accommodate natural processes. Two general approaches offer significant promise for providing this system capability. Each takes advantage of or accommodates natural processes. The first approach (Capability 2.1) is to engineer the thermobiogeochemical environment to limit the volume, toxicity, and/or mobility of contaminants. The second approach (Capability 2.2) uses barriers that continue to function over extended periods by mimicking natural processes and accommodating environmental change.

Capability 2.1 Engineer the thermobiogeochemical environment to limit contaminant toxicity and mobility

Contaminant toxicity and mobility are strongly influenced by the physical characteristics and chemistry of the contaminant and its surrounding environment. Techniques to control these attributes could target contaminants at the ***source*** (including, for example, landfills, disposal trenches, tanks, and contaminated soils at spill sites) or in the ambient environment (notably including ***groundwater*** plumes). The roadmap team established one 2008 S&T target for control at the source and a complementary target for engineering the thermobiogeochemical characteristics of groundwater environments.

2008 Target for Capability 2.1 (Target 2.1a). Deploy alternative technologies that detoxify or immobilize risk-driving contaminants at the source.

2008 Target for Capability 2.1 (Target 2.1b) Deploy alternative technologies that reduce the volume of groundwater that would otherwise have been pumped and/or treated.

Achieving these targets will require developing and demonstrating a variety of physical, chemical, and biological manipulations that destroy some contaminants and control the toxicity and mobility of others in the diverse environments encountered in the DOE complex. No single technology or suite of technologies could provide the full range of capabilities required across the complex.

Some of these technologies could reduce stewardship requirements by allowing more aggressive remediation. For example, demonstrated technologies for destruction of organic contaminants in the environment could be applicable to some source zones and groundwater plumes in the DOE complex. However, additional development effort is needed to extend these technologies to the greater depths and complex geologic settings encountered at some DOE sites.

Biological techniques, including enhanced bioremediation, engineered wetlands, phytoremediation, and monitored natural attenuation, also have promise for reducing contaminant volumes and water treatment needs at locations contaminated with organic compounds or nutrient-rich explosive compounds (for example, energetics containing fixed nitrogen). For successful immobilization and detoxification of long-lived contaminants such as metals and most radionuclides, approaches that offer the greatest promise include those that emulate natural systems in which similar materials have remained stable over extensive periods. For example, in situ redox manipulation, bioremediation, and permeable-reactive-barrier systems all can stabilize contaminants by creating geochemical conditions that favor formation of stable compounds or by stimulating microbial communities to create such conditions. Thermal treatment techniques can reduce contaminant mobility by altering the physical setting, as in thermal desorption or vitrification, as well as by altering the rate of chemical changes.

Capability 2.2. Design, build, and operate alternative (next-generation) containment systems

Current designs for surface barriers (covers and caps) attempt to block contaminant release processes such as water flux, erosion and biointrusion. These designs have failed in the short term because their barrier capability degrades with time. An alternative approach for designing, building, and operating sustainable covers mimics elements of natural landscapes that have already passed the test of enduring over time. This approach could substantially reduce system life cycle costs, which include costs for repair, replacement, and institutional control. Health risks to workers would be reduced by reducing active interventions for repair and replacement of deteriorating containment units. Long-term risks to the public would be reduced if the natural robustness of surface containment systems was improved (less risk to the public in the event that maintenance efforts lapse). Similar improvements could be achieved by applying these principles to design of subsurface containment barriers.

This capability is most likely to be effective when the containment system design integrates *natural analogues* into design, construction, modeling, and monitoring. For example, substantial progress has been made in developing alternative cover systems that mimic the geomorphology, soils, and ecology of natural settings that exhibit favorable attributes for long-term containment.

For example, evapotranspiration cover designs rely on a soil "sponge" layer to store precipitation. They use natural vegetation to return infiltrating precipitation to the atmosphere. Short-term studies show that evapotranspiration covers can be more effective than conventional designs in containing contaminants in subhumid to arid climatic settings, while reducing maintenance intervention and land-use controls during long-term stewardship.

Broader application of this natural analogues approach will require additional work to validate performance, as well as site-specific studies to optimize the technology for new locations and establish feasibility. Extending the approach to designs for humid-climate sites, such as Fernald, Oak Ridge, and Savannah River, will require further research, such as studies to identify humid-region vegetation succession patterns that are compatible with cap/cover survival and that require less maintenance than mowed grass.

With respect to subsurface barriers, system life cycle costs could be reduced by a variety of enhancements to existing technology. Examples of promising techniques include:

1. Improved technologies for emplacement of slurry walls, grout curtains, and horizontal grout curtains
2. Techniques to increase barrier life by stimulating "self healing,"
3. Identification and development of barrier materials that are chemically and physically compatible with site-specific contaminants and geologic settings.

As with Capability 2.1, the roadmap team defined two S&T targets for this capability: one specifically for cover systems (surface barriers), the second for subsurface barriers.

2008 Target for Capability 2.2 (Target 2.2a): Deploy cover systems that mimic natural processes and accommodate environmental change.

2008 Target for Capability 2.2 (Target 2.2b): Deploy subsurface containment systems that mimic natural processes and accommodate environmental change.

2.2.3 System Capability 3. Conceptualize and Predict Containment/Control System Performance, Potential Failure Modes, and Levels of Failure

Most existing CC&C units have not been designed or tested for long-term survivability. Consequently, DOE must plan for aggressive (and costly) long-term stewardship programs to ensure their effectiveness. Current approaches to performance assessment implicitly assume that long-term environmental changes can be captured with numerical extrapolations based on monitoring ambient conditions in field tests for a few years. The Uranium Mine Tailings Remedial Action (UMTRA) stewardship project and others are finding that the performance of engineered covers changes in ways that cannot be predicted using numerical models and short-term field data.

There are experimental cover/cap systems that could be monitored and tested over the next five years and beyond to improve understanding (and thus prediction) of their responses to climatic cycling and biological processes. General knowledge of the processes that affect CC&C systems (including ecological succession, seismic effects on earth structures, erosion, pedogenesis, and other natural processes) could be applied in predicting the long-term performance of these systems. Also, natural, historical, and archaeological analogues (such as Native American burial mounds and old concrete) exist for some cap/cover systems and engineered waste forms. These analogues can be studied to learn about the specific effects of less-frequent phenomena (such as earthquakes) and longer time periods.

Improved capability to predict system responses to various expected or potential environmental changes could, by 2008, substantially reduce both costs and uncertainty of long-term stewardship for sites with engineered caps or covers. Routine inspection and monitoring could be safely reduced to focus on just the key target contaminants, surrogates, and locations. Repairs and replacement would be less frequent because prediction of time to failure would be more reliable and specific systems requiring repair could be identified more accurately. Cost savings will be greatest if the research and test results are available in time to influence final closure designs. For caps, covers, and engineered waste forms, improved prediction of time to failure and knowledge of the characteristics of "failed" system could lead in the near term to a significant reduction in uncertainty—perhaps 50 percent—for predictions of long-term consequences at most DOE sites.

2008 Target for System Capability 3: For incorporation in software modules and other technologies available through the LTS Technology Store, provide performance data on experimental cover/cap systems and natural analogues, models for long-term natural processes that affect the performance of CC&C systems, and improved methodologies for prediction of failure modes and time to failure. [RK4]

As the wording of this S&T target implies, its products are intended to feed into tools made available to stewardship planners and managers through the LTS Technology Store. See in particular Capability 8.1 and S&T Target 8.1a (Section 2.5.1).

2.3 MONITOR THE SITE AND THE LTS SYSTEM

Currently, site monitoring systems are developed as an add-on at the end of the remediation plan. These systems are typically designed using a "cookie cutter" approach—one size, shape, and set of components fit all sites. The state of practice at DOE closure sites is now 25 years behind the state of the art in designing and implementing site monitoring systems. This approach leads to LTS monitoring systems whose life cycle costs will grow, even over relatively short periods, to represent multiples of the site closure cost. For example, DOE already spends more than $300 million per year for site-wide water analyses[RK5]. The lack of a site-tailored, system-engineered monitoring plan also results in higher risks to health and the environment and greater technical uncertainty than the state of the art in planning and system design could provide.

State-of-the-art systems reduce cost and uncertainty, increase robustness and longevity, and decrease risk by allowing implementation of contingency actions promptly, while they are technically feasible. Developing a ***framework*** for the monitoring system permits it to be optimized for an individual site. Consequently, risk reduction can be accelerated while cost is reduced and efficiency of closure is increased.

Under the Monitor function, only the following capabilities are covered: (1) selecting sensor technologies and sensor systems and (2) identifying monitoring needs and filling sensor technology gaps. The S&T support for these capabilities will result in tools and technology options for the LTS Technology Store. Capabilities for design, installation, and validation of monitoring systems, as part of the larger LTS system, are covered under System Capability 8, System Performance Validation and Monitoring. Operation and maintenance of monitoring systems are covered under System Capability 10.

2.3.1 System Capability 4. Selection of Sensors and Sensor Systems for Site Monitoring

Before a site is transferred from closure operations to stewardship, site monitoring systems must be deployed. Each monitoring system consists of an array of detectors (also called sensors or monitors) deployed in a tailored or graded approach to provide real-time detection and analysis of selected indicators. These indicators may be contaminants or contaminant surrogates, parameters relevant to performance of CC&C units, or signals indicating the status of physical access controls (e.g., human or animal penetration of a barrier and other barrier integrity indications). These detectors and the communications links from them should be selected to:

1. Reduce requirements for stationary laboratory sampling and analysis
2. Provide the levels of replication, detection, and precision needed to (a) comply with regulatory or locally based requirements for the site, (b) protect the community at risk and site access area, and (c) provide early indication of imminent or potential failure, or other need for corrective action, in some element of the overall LTS system.

The effort to provide this system capability must begin now, to reduce substantially the following negative consequences of current capabilities and approaches:

4. Last-minute interruptions from stakeholders concerned that their communities are endangered by inadequate monitoring and early-warning capabilities at the site
5. Costly last-minute work-arounds for unplanned needs
6. Costly, labor-intensive efforts by the site steward to operate and maintain monitoring systems
7. Inability to integrate commercial successes, such as avoiding costly single-point failures in monitoring systems
8. Loss of capability to design for efficient, optimized maintenance.

Capability 4.1. Sensors and sensor systems for contaminant monitoring

Contaminant monitoring systems for long-term stewardship must be designed to cost-effectively collect data that ensure ***long-term*** protection of human health and the environment at sites with residual contamination and engineered CC&C systems. Current approaches to monitoring systems often focus on ***short-term*** monitoring plans, in which data are collected from numerous locations above-ground and at multiple depths below-ground. These data are usually collected quarterly and analyzed for an exhaustive list of constituents of concern. These comprehensive monitoring systems have not been optimized for long-term monitoring, where the goal should be to assess changes in site conditions as cost-effectively as possible. (Scarce resources are better spent on reducing risks, rather than accumulating excessive data that adds little value to ongoing site performance assessment.) For the objectives of long-term stewardship, a site-specific monitoring system should be designed to reduce uncertainties and risks, while avoiding unnecessary costs. The ability to emplace these systems in the field cost-effectively needs further development.

Capability 4.1 assumes that enough data regarding the residual contaminants of concern (source terms) within the 2006 sites will be available that a set number of sensors, hardware, and other components can be assembled as technology options for site-specific selection and tailoring. These sensor system components and the design/selection methodology to use them effectively will be included in the LTS Technology Store.

2008 Target for Capability 4.1 (Target 4.1a). Deploy in the LTS Technology Store a set of peer-reviewed contaminant monitoring options and a methodology for selecting and tailoring the contaminant-monitoring subsystems of site performance and safety monitoring systems.

Even if the state of the art in sensors (detectors), transmitters, and data analysis/interpretation software were made available, a key component in effective and efficient design of contaminant monitoring systems is knowing what needs to be monitored and what does not. Thus, a second S&T target for 2008 for this capability is to ***identify surrogates and/or indicator parameters*** for a wide range of contaminants of concern at DOE sites progressing toward closure and stewardship.

2008 Target for Capability 4.1 (Target 4.1b): All DOE sites in or moving toward stewardship have incorporated appropriate surrogates and indicator parameters in their site monitoring plans for implementation by 2010.[RK6]

Achieving Target 4.1b would allow stewardship planners and managers to design a contaminant monitoring system that focuses on detection of critical changes in site conditions, rather than continually collecting data on numerous specific chemical constituents. Surrogates and indicator parameters that can be monitored to identify changes significant for protecting health and the environment, rather than monitoring a complete suite of analytes, must be identified, proven, and accepted by the appropriate regulatory bodies and other stakeholders.

Capability 4.2. Sensors and sensor systems for monitoring active and passive safety systems

This capability is intended to provide an LTS steward (planner or manager) with tools and options responsive to a generic set of safety system specifications. These specifications would reflect all of the requirements for monitoring the passive and active safety subsystems on the site. The monitoring tools and options would include hardware, sensors, and monitors, as well as a methodology for selecting and tailoring site-specific monitoring systems from these components.

Performance monitoring data for passive safety systems can include signals for intrusion, erosion, topographical changes, and source term breaches. The monitoring systems to provide these signals should be able to discern incidental, chronic, or deliberate intrusions within controlled areas. The signal modes that would be integrated might range from satellite imagery to seismic pressure transducers with radio frequency output, to vapor and metal detectors operating on radio frequency. (Performance monitoring for active safety systems is discussed under Capability 8.4.)

Each monitoring subsystem must be capable of connecting into a main risk-data integration system (the data integrator). Such a system will be capable of transmitting the various safety system signals arrayed for both passive and active protection and providing both real time (alarming or warning) data and compiling historical trending data. This system also measures functionality attributes indicating whether the various safety systems are performing as required. For example, in the active sensors, it could be as simple as a small indicator light being on or off. The risk-data integration system should itself be a component of the larger site information and performance monitoring system for storing, trending, signaling, and activating additional systems and alarming on pre-selected tolerances (see System Capabilities 6 and 8). It should be packaged in a standardized format to provide cost savings and increased reliability across the 2006 closure sites (as well as sites closed after 2006).

Automated monitoring subsystems for site safety systems, comprising arrays of embedded instruments, cannot entirely replace the need for manual collection and analysis of samples. However, a reasonable goal is to reduce the amount of stationary sampling by 40 percent from the level anticipated without automated monitoring, thereby reducing the associated labor costs by 40 percent.

2008 Target for Capability 4.2. Deploy in the LTS Technology Store a set of peer-reviewed safety system monitoring options and a methodology for selecting and tailoring the monitoring subsystems for active and passive safety systems, to reduce capital and operations and maintenance costs by 40 percent during the first ten years of the LTS, with anticipated increased savings during out decades.

2.3.2 System Capability 5. Identify Multimedia Contaminant Monitoring Needs and Fill Sensor Technology Gaps to Meet Those Needs

Users of the LTS Technology Store will need a methodology, incorporated in one or more user-oriented software tools, to select components for contaminant-monitoring subsystems tailored for the conditions and objectives specific to the site. The methodology must take into account the multiple routes by which exposure may occur: transport by air, by surface or subsurface water, in precipitation, through disturbance and transport of solids on the surface, or by biotransport on the surfaces of or within plants and animals. The methodology must also be compatible with the conceptual models developed under System Capability 1 for the LTS Technology Store, so that users have an integrated solution to their LTS system planning needs.

Capability 5.1. Establish criteria for health exposure for occupational and non-occupational (community at risk) routes of exposure

Lasting and scientifically defensible criteria must be developed to provide proper protective responses to action levels and warning levels of target contaminants. To account for differences in cumulative dose, routes of exposure, protective systems, and risk acceptance by individuals who may be exposed, two sets of criteria are needed: one for occupational routes of exposure, the other for non-occupational routes (those faced by individuals in the community at risk).

Occupational routes of exposure apply to persons who are authorized to enter the site barriers for reasons of maintenance, inspection, cultural visitations, etc. This subpopulation at risk will be governed, monitored, and tracked for exposure based upon the regional, state, or other public entity that has jurisdiction. Exposure levels for chemical and radiological hazards set by the various state jurisdictions, such as ecology or health departments. For chemical hazards with federally established regulatory levels, identifying credible groups at risk is simplified. The applicable exposure standards are continually updated to reflect current epidemiological and toxicological information. There is therefore no need for an S&T target to augment, change, or add additional criteria for exposure to chemical, biological, or radiological materials for the occupational group. The current standards can be incorporated in the tools developed for selecting site monitoring systems.

As discussed above for Capability 1.3, the community at risk includes anyone who resides near or routinely visits an area adjacent to the site boundaries (which will change over time). There are no regulations for 24-hour or domicile-based exposures to small quantities of chemical hazards over a prolonged period. However, monitoring targets (hazardous agents themselves or established surrogates) can be selected, based on the totality of potential contaminants of concern and the credible pathways by which they may be liberated from containment on the site and transported into the areas defining the community at risk. A defensible, credible methodology is needed, which could be used to establish non-occupational threshold limits.

The framework developed for identifying the community at risk (see Capability 1.3) must interface with whatever tools are developed to incorporate the methodology for establishing exposure criteria for this population.

2008 Target for Capability 5.1: Provide tools for the LTS Technology Store that derive monitoring system targets (hazards or surrogates), thresholds, and action limits from defensible, credible methodologies for establishing criteria for both occupational and non-occupational exposures.

Capability 5.2. Identify contaminant monitoring needs for all media of potential transport or exposure and fill sensor technology gaps where monitoring solutions are needed

LTS will require the development of multimedia (subsurface, surface, airborne, in-building) sensor technologies or techniques that either improve the capacity to monitor the presence and concentration of contaminants (or surrogates) or significantly decrease the cost of existing monitoring techniques. New sensors and sensor-system technology are needed to measure GHBCT analytes and surrogates (see Capability 1.1), monitor remotely and wirelessly, miniaturize existing sensors, and increase reliability and calibration. The road-map team estimated that new sensors that reduce the need for invasive techniques would reduce costs for monitoring contaminants (or surrogates) and control/containment performance by 25 percent. Increasing the accuracy and reliability of sensors will reduce uncertainty and cost by a factor of two.

Techniques that allow for remote operations through telemetry or wireless technology are of interest, as are techniques, which in conjunction with modeling processes, allow for optimization of monitoring and/or CC&C systems. In-situ techniques for developing GHBCT surrogate and analytes are needed that provide reliable data for the integrated LTS system performance monitoring capability (System Capability 8). Improving the reliability of the system will decrease the need for replacement and maintenance (System Capability 10). These new technologies must also improve or decrease the cost of maintenance or replacement to be effective. In addition, self-calibration of the systems will improve the reliability of the monitoring data. Software development will provide a user-friendly interface to aid data integration and dissemination (System Capability 6).

The S&T target established by the roadmap team for this capability includes development of tools for the LTS Technology Store with the following capabilities:

9. Identify the monitoring needed for different sites and transport media.
10. Match the specific needs with existing and developing monitoring technologies.

- Identify technology gaps for which new technology is needed.

In addition, the R&D pathway includes the capability to initiate and complete the technology R&D to fill the identified gaps. Sensor technologies for multimedia environmental monitoring will be needed that incorporate new and innovative approaches to developing hardware, applications, and software. Hardware development may include new GHBCT methods, wireless miniaturization, remote interrogation, and non-invasive techniques. Applications and software will be developed to integrate point-volume sensing and to increase the reliability and calibration of sensors used in site monitoring systems. LTS sites will benefit particularly from remote, in situ, and continuous monitoring devices that yield real-time information or that can detect pollutants at very low concentrations.

2008 Targets for Capability 5.2:

11. Develop technology to fill 30 percent of identified gaps.
12. 10 percent of sensor arrays in field can deliver data wirelessly from subsurface.
13. In-situ analysis can be done in subsurface for 5 high-risk analytes or surrogates.
14. Assure that, 30 years out, 50 percent of sensors still meet their performance objectives.
15. Application of volume integrating methods, including non-invasive techniques, will increase to 10 percent application in areas such as soil moisture and leak detection.

2.4 COMMUNICATE WITHIN AND BEYOND THE LTS SYSTEM

All DOE sites have an existing need to provide information to the public regarding site activities, environmental contaminants, associated hazards and risks, and the status of remedial actions taken to mitigate and/or monitor those risks. The users of this information include local residents and community leaders, who have a direct interest in these site activities. As discussed in Chapter 1,[RK7] these information users must be viewed as included ***within the stewardship system*** as a whole. The historical examples of how institutional controls fail or endure over extended periods point to the importance of embedding those controls in more general societal institutions, such as the informal but powerful social relationships that define concepts such as ***community*** and ***civil society***.

Beyond the local communities that interact with the stewardship site directly and are clearly integral to a long-term stewardship system, there are other concerned parties such as members of Congress, federal, state and local agencies other than DOE, regulators, researchers, and entities in the for-profit business sector. Whether these parties are viewed as being integral to the stewardship system or are external to it will depend on site-specific and time-dependent characteristics. However, they, too, will need information from the site's communications subsystems and may at times become sources of information for those subsystems. Thus, without trying to be too precise about the exact boundaries of the system, one can conclude that it needs to be able to communicate within itself and externally to a range of interacting parties.

2.4.1 System Capability 6. Collection, Assimilation, Visualization, Evaluation, Dissemination, and Management of Information about the Site

The roadmap team identified specific technologies that need to be developed and or demonstrated to ***communicate information about the site***, both within and beyond the stewardship system. Methods and tools are needed to sustain knowledge about, and inform refinements to, the integrated subsystems of the stewardship system. These subsystems typically combine natural, engineered, and human subsystems or components.

More specifically, methods and tools are needed to:

16. Obtain and transmit information about these subsystems and components (technology examples: on-site observations; remote, automated data collection; electronic, wireless, or optical transmission of collected data)
17. Extract, integrate, and evaluate information (technology examples: mechanisms to evaluate statistical data-quality; artificial intelligence methods; mechanisms for integrating data functionally across platforms, formats, and forms; harmonizing taxonomies and network topologies)
18. Interpret and display information according to the needs and requirements of diverse information users (technology examples: statistical and geographical/temporal trend analyses; visualization and decision-support mechanisms)
19. Maintain, store, and archive information so as to both preserve it and make it readily accessible when needed (technology examples: compressed holographic optical disk storage; warehousing; traceability; centralized and distributed architectures)

- Access and communicate stored/archived data and other information (technology examples: streamlined accessibility; tailored reporting; interactive communication).

The following benefits can be expected from funding the effort needed to achieve the S&T Targets for 2008 discussed below for Capabilities 6.1 through 6.3:

20. Avoid last minute stakeholders, regulators, intervention, and fees
21. Avoid using outdated equipment and technologies
22. Eliminate labor intensive activities
23. Eliminate workarounds
24. Substantially reduce the risk of human error
25. Automate remote decision processes
26. Capitalize on commercial-sector successes
27. Provide comprehensive profiles of site conditions (to support defense in depth)
28. Reduce single-point failure modes
29. Reduce unnecessary, repetitive, duplicative monitoring

- Enable extrapolations and optimization of expected maintenance activities and costs.

Capability 6.1. Integrated information visualization and display system

All sites across the DOE complex need to collect, analyze, and provide site-specific information on site environmental conditions, remedial actions, contaminant plumes, and monitoring programs to a variety of concerned or involved parties. These parties include site workers, program managers, regulators, and interested personnel at other DOE sites or at DOE headquarters. DOE sites are currently required to collect, evaluate, and communicate environmental data and interpretations to both DOE management and regulatory agencies on a periodic or as-needed basis. Means for presenting and disseminating this information to involved parties already exist, but they exist at different levels of development, complexity, and sophistication. They exist in a variety of presentation formats, and typically only provide information weeks, months, or more after the original data were gathered. Further, this information may not be readily available to interested parties at other sites across the complex with similar interests or contaminant concerns.

An integrated, complex-wide, web-based, upgradeable, information visualization and display (IV&D) system, fully capable of presenting information ranging from raw data to graphic displays of data, on as near a real-time basis as state-of-the-art technology allows, would promote management coordination, efficiency, and decision making. It would benefit the DOE LTS Program as a whole.

Current technology is a start, but it needs to be implemented, not just site-wide but complex-wide. For instance, a shared information and knowledge base is needed. Commercial vendors have developed information systems with these capabilities for the oil industry, but some R&D is needed to adapt available approaches to DOE site activities. Beyond adapting existing capabilities, new technology or approaches are needed for analysis, data mining, and trend analysis of incoming data. New technology is needed for visualizing monitoring data in ways that different categories of users can understand and use. Technology must be developed or adapted for wireless or other networking of systems.

The development of an integrated public outreach program, for which the public access portion of the IV&D system would be the information technology foundation, would benefit DOE's interaction with the public by providing for information and feedback in both directions. Educating the public with respect to ongoing remedial activities, proposed monitoring techniques, and technological advances would help to gain the public's confidence and foster support for the LTS Program. Educating the public with respect to known or potential hazards and corresponding risks will help mitigate the public's fear of those risks and facilitate acceptance of the LTS Program. Finally, providing readily available means, through the IV&D public access interface, for stakeholders to respond with comment and information for site stewards is not just good public relations. It is fundamental and essential to continuation of stewardship activities over extended periods.

2008 Target for Capability 6.1: Have in place at all DOE stewardship sites (and others working toward closure) a mature, functional, web-based information management and communication system that is shared across the DOE complex. This system is to include two principal parts:

1. An internal communications system designed to accommodate data storage, data validation, user access, information dissemination, and visualization, to be used primarily by site personnel for their internal communications and to facilitate communication with DOE headquarters staff and regulators

2. An external communications system designed to facilitate public outreach and education, including feedback and response from the public to site stewards.

Capability 6.2. Performance data communication module

A component of Capability 8.4 is the capability to communicate (disseminate) monitoring and evaluation information on LTS system performance. Thus, the IV&D system described above for Capability 6.1 should include modules for access, visualization, and display of information on performance of the site's CC&C, monitoring, and access control systems.

The roadmap team did not define a 2008 S&T target specifically for this capability. The S&T targets for Capability 6.1 and 8.4, if implemented as an integrated system, should suffice to provide this capability.

Capability 6.3. LTS Technology Store options for intergenerational information archiving

Optimal technical and administrative management of a LTS site requires planning for future failure or disruption. If a safety system or contaminant containment fails in the future, those responsible for responding must be able to obtain information to understand the risk and repair the failure. A system is needed to preserve and hand down, across multiple generations, information that identifies site boundaries, defines the operation and maintenance of surveillance systems, keeps the community at risk aware with onsite markers, and communicates technical data (e.g., the contaminants of concern and the containment and monitoring designs for the site).

This system, called here an ***intergenerational archive***, must provide responsible, responsive, and reliable storage and retrieval for intergenerational data. The purpose of an intergenerational archive is to reduce the uncertainty that information will be accessible when needed by ensuring that site information is preserved from intergenerational technical continuities.

The information that must be preserved and communicated across generations includes information needed to protect people, secure a site when residual hazards are still present, and perform maintenance required by the technology or structures in use to contain and control residual hazards. There are numerous stories about failures to communicate or preserve this essential site cleanup and closure information.

30. At one cleanup site, a landfill was capped. An operator was asked to move a bulldozer to a nearby forest for clearing. Unaware of the capped landfill, the operator drove the bulldozer over it, causing substantial damage to the cap.
31. In numerous instances, state or local utility department crews open up underground utilities where hazardous materials have been buried, unexpectedly exposing themselves to the hazards. When the presence of the hazards is discovered after the exposures, there are decontamination and liability costs, as well as increased health risks.
32. There are numerous accounts of sudden subsidence under the weight of a vehicle driven on old, unmarked burial grounds.

33. For many old facilities, drawings or other accurate engineering information are no longer available, or they prove to be inaccurate.

The goal is to maintain information over the long term, regardless of the medium used by new information technology. The intergenerational archive will need to include photographs, maps, administrative reports, blueprints, specifications, and other means of conveying detailed information accurately. Another important function of an intergenerational archive is to support continuity in land-use controls. (See Capability 9.2 for further discussion of this aspect of the archive.)

Developing an intergenerational archive will reduce costs by eliminating the need to reproduce the science and technology when repairs and improvements are made to LTS sites. It will decrease uncertainty and risk by providing reliable and accurate data about the site cleanup and closure, as well as technical information about containment and control of residual contamination and the monitoring systems for the site.

2008 Target for Capability 6.3: Provide technology and information system options through the Technology Store to enable stewardship sites to plan, implement, and maintain an efficient, optimized intergenerational archive.

2.4.2 System Capability 7. Establish and Maintain Site–Community Communications

The DOE has a long-standing lack of credibility when it comes to cleanup of the nuclear weapons complex. Charges of untrustworthiness, incompetence, and conflict of interest emanate from the private sector, the media, government leaders and regulators, and the public interest community. In a recently released report, the Office of Environmental Management within DOE stated that, over the past ten years of the DOE environmental management program, there has been little substantive progress (DOE 2002).

Substantive community involvement in the design and conduct of LTS plans and activities will help to build the credibility of institutions responsible for long-term stewardship. Cleanup and long-term stewardship efforts are also more likely to reduce environmental and health risks in both the near and long terms when the community at risk is involved. In contrast, a public that feels excluded from cleanup and LTS decision processes is more likely to become suspicious and openly hostile. (A good example is the advocacy by the Federal Facilities Environmental Restoration Dialogue Committee of site-specific advisory boards in the face of funding shortfalls.)

A 1996 report by a National Research Council study committee, *Understanding Risk: Informing Decisions in a Democratic Society*, argues that better decisions are made—and controversies around risk decisions are better resolved—when all interested and affected parties are involved at the earliest possible point in both the characterization and analysis of risk. The report advocates an analytic-deliberative process, which entails a truly substantive public participation process involving the full range of interested and affected parties, decision makers, and technical specialists (NRC 1996).

Whether this approach or an alternative is adopted, the fundamental point is that the communities surrounding a stewardship site must be viewed as an integral part of the larger stewardship system for the site. If this component is not functioning effectively to support and sustain the containment, monitoring, access control, and communication objectives of the stewardship system, the system will fail long before the intended duration of site stewardship.

Capability 7.1. Involve the community in the conduct of site stewardship

Efforts to foster public participation around DOE sites have met with mixed results. A large body of literature exists on specific incidents in fostering (or obstructing) effective public participation in decision making. However, objective measures are lacking for the effectiveness of the many suggested approaches.

Substantive community involvement in the design and conduct of long-term stewardship may also result in significant cost savings. In a recent report to DOE, another National Research Council study committee recommended that, to address the risks and uncertainties of long-term stewardship, a systematic approach to cleanup be developed in which contaminant reduction, contaminant isolation, and stewardship are considered in an integrated and complementary fashion (NRC 2000).

If long-term stewardship begins with agreement on future site uses, end states, and remedies, then the potential for near-term and long-term cost savings are great. Community involvement in cleanup decisions has already saved millions of dollars for DOE. At times the identification and advocacy of these cost savings has been initiated by local communities (e.g., for the Hanford and Rocky Flats sites). In some instances, short-term cost savings by over-reliance on engineered or institutional controls appear likely to result in larger costs over time because of additional monitoring, maintenance, and rework to remedy failure.

Communities near closure sites are likely to be vigilant in assessing remedy selection decisions. An example is the “toolbox” for identifying and organizing the long-term activities necessary for a site stewardship program, described in a report by the Rocky Flats Stewardship Working Group (RFSWG 2001). Other examples include those sites listed in Chapter 1 as already facing community intervention in DOE closure plans and schedules (Amchitka Island, Alaska; Weldon Springs, Missouri; and Mound, Ohio).

2008 Target for Capability 7.1: Design and implement a stewardship program, suitable for DOE sites entering long-term stewardship, that aligns DOE and community objectives.

Capability 7.2. Learn what affects public trust and confidence

The development of viable long-term stewardship at a site will require that communities have a high degree of trust and confidence in those entities charged with designing and administering the LTS program. Either passive lack of public support or an adversarial relationship with the public could spell disaster for the viability of LTS at a site. The 2000 National Research Council report on long-term institutional management said that DOE should expect failure and plan for uncertainty and fallibility (NRC 2000, pp. 4–5). However, if the public's trust and confidence can be gained and maintained, the chance for success increases. Further, DOE will likely realize both short-term and near-term cost savings if it can build a cooperative relationship with the public affected by and interested in a stewardship site. In such a situation communities will be more likely to try innovative approaches to site cleanup, containment and control of residual contamination, and site monitoring.

Research is needed to determine:

34. What engenders public trust and confidence
35. What effective public participation looks like, including further examination of the analytic-deliberative process
36. How to measure effective public participation
37. How to replicate successful public participation efforts.

This research should include case studies of public participation efforts inside and outside DOE, pilot public participation efforts in long-term stewardship, and analysis and suggestions for replication of practices deemed successful.

2008 Target for Capability 7.2: Finish case studies of agency actions that do or do not engender thrust and confidence. Initiate full-scale field use of successful actions at selected sites.

Capability 7.3. Identify and solve problems that can undermine reliability and consistency in LTS institutions

Effective stewardship is a combination of technical and human achievement. No matter how advanced the engineering and technical feats are, LTS will be diminished to the extent that social organization fails. Yet failure is both normal and necessary. That is, there is no such thing as error-free operation. While it is possible and desirable to learn from successes, learning is broader and deeper when the range of experiences faced by an organization is wide enough to include failures. Thus, not only should we expect failure, but—unless it is too severe—we need to welcome it. The tasks are daunting. We need to:

38. Foster organizations that are adaptable to new knowledge and new circumstances regarding risk, science, and concerns about legitimacy
39. Assume that organizations will fail and to devise organizational arrangements that will channel information about their own failures, as well as those of other organizations, so that learning and adaptability are enhanced
40. Identify the major forms of institutional failure and success and improve institutional reliability and performance.

2008 Target for Capability 7.3: Design and implement institutional mechanisms that sustain and improve long-term stewardship.

2.5 MANAGE THE LTS SYSTEM

The safety systems and institutional controls, CC&C systems, and communications systems implemented at a site require ongoing operational *technical management* (for the technical elements of these systems) and *administrative management* (for the nontechnical elements). Successful management of these subsystems of the total LTS system for stewardship of a site means meeting multiple stewardship objectives—including but not limited to regulatory requirements.

For example, the land use plan for a site may assume that passive and active access controls always operate at performance levels that ensure defense in depth. Safety systems and institutional controls are required at LTS sites to protect the public from environmental insults. This public includes individuals who can gain access to formally restricted government property, as well as individuals living in adjacent or nearby communities at risk. Physical systems for protection and (safety systems) are necessary because purely institutional forms of control (administrative, social, or legal controls for keeping people out of harm's way) can be fractured over time or ignored by individuals at any time. Local zoning laws and restrictive covenants are fragile as long-term controls because they can be changed or liberalized over time, in response to economic or social pressures.

At the same time, cost efficiency in performing these essential activities is important. Optimization of the administrative and technical management activities aims at achieving all these performance outcomes in the best way (an optimal total systems solution).

2.5.1 System Capability 8. LTS System Performance Validation and Monitoring

Effective long-term stewardship requires reliable technologies to validate and monitor the various subsystems that contribute to the total LTS system for a site. These subsystems include the CC&C systems on the site, the human health and environmental safety systems both on and off the site, and the institutions with stewardship responsibilities.

The objective of subsystem validation and monitoring is to ensure that the planned performance levels of all the technical and non-technical subsystems are truly being met on a continuing basis. Open and well-documented ***validation*** procedures are necessary to assure the public and regulators that no incremental or additional risks to human health or the environment are occurring when these various systems are first installed and made operational. Thereafter, regular ***revalidation*** answers the question, "Is the total system still operating according to plan?" Periodic ***re-evaluation*** addresses the broader question, "Is the plan still effective for meeting all stewardship goals?"

Both revalidation and re-evaluation are essential to maintain effective stewardship over time, just as the initial validation is essential to ensure that new systems are operating as planned. For example, the software and hardware packages and subsystems that control and validate day-to-day safety system and access control operations must be re-evaluated at a regular interval for continued relevance to site objectives, advances in technology, and obsolescence. Nontechnical subsystems (e.g., administrative procedures for institutional control and information management) also require reassessment at a regular interval to ensure they remain adequate, responsive to change, and cost-effective.

The roadmap team rated System Capability 8 as having a high impact in reducing technical uncertainty and risks to health and the environment in the near term. The team defined eight S&T targets, covering the following aspects of this general System Capability:

41. Improvements to capabilities for planning and designing CC&C systems, including their associated contamination and performance monitoring subsystems, and improvements for support to decision processes during stewardship, made available to sites through the LTS Technology Store (three S&T targets under Capability 8.1)
42. LTS Technology Store module(s) for validating performance of CC&C subsystems and monitoring subsystems (Capability 8.2)
43. LTS Technology Store modules for validating and re-evaluating safety system effectiveness (Capability 8.3)
44. LTS Technology Store system performance module for the sitewide IV&D system (Capability 8.4)
45. Institutional procedure for periodically revisiting cleanup/stewardship decisions to ensure continuous improvement (Capability 8.5).

Capability 8.1. LTS Technology Store options for techniques and technologies to improve planning, design, implementation, and decision-support capabilities of CC&C systems and their associated monitoring systems

Monitoring will be required to both verify containment system performance in the short term (demonstrate that an installation achieved specific performance goals) and continue monitoring performance over the long term. Long-term monitoring should (1) confirm that containment systems have not been breached and (2) provide early warnings of changes indicating that preventive response is needed. Long-term monitoring of CC&C systems should also validate or refine projections of performance and risk reduction. Most existing and proposed performance monitoring schemes rely on arrays of point sensors that will probably need to be replaced *within ten years*. These current systems are unproven and will be costly in the long term.

The roadmap team identified eight areas[RK8] in which improvements are needed to meet the above requirements for monitoring CC&C systems.

Site-Specific Performance Requirements. Generic or prescribed performance requirements for engineered CC&C systems are well developed. However, these requirements do not yet fully account for environmental settings and other local factors. Nor are they being deployed for sustained effectiveness and efficiency over successive generations. LTS planners and managers need guidance for deriving site-specific performance requirements based on characterization of current and possible future environmental settings, projections of contaminant release processes and pathways, and assessments of associated human health and ecological risks.

Integrated Model of System Failure Modes, Release Processes, and Exposure Pathways. Basic methods for identifying generic failure modes and release processes are well developed. So are general, idealized transport and fate models and a standard exposure assessment methodology. However, these pieces are not yet integrated into a systemic approach to site-specific modeling of waste sources, CC&C configurations, and environmental settings (see Capability 1.2 and System Capability 3). Nor have the existing methods and models been validated or verified for site-specific conditions. Current models still represent fairly simple cases. They are not yet well enough developed to accurately represent real processes in heterogeneous environments, such as flow in fractured media, other preferential flows, site-specific attenuation characteristics, or susceptibility to and recovery from exposure effects.

CC&C Design and Performance Assessment Tools that Incorporate Analogues of Long-Term Environmental Change. Current performance assessment tools (short-term prototype tests, monitoring, and modeling) inadequately predict changes in the performance of CC&C systems in response to long-term environmental change. Reasonably well-developed methods from the natural sciences can be adapted for identifying and characterizing natural analogues for a range of system features (see Capability 2.2). Incorporation of location-appropriate analogues of natural processes into CC&C system design and performance evaluations could greatly strengthen system resilience to inevitable environmental changes. Not only will these alternative systems be much more effective; they will be much cheaper than current systems, which require extensive active management and maintenance to offset the impacts of natural processes. However, methods for integrating analogues with modeling and monitoring into evaluations of the long-term performance of CC&C systems are not yet well developed and are not yet widely deployed.

Selection of Monitoring Parameters and Criteria for Integration with CC&C Systems. Methods for choosing performance monitoring parameters and locations for basic CC&C systems are reasonably well developed, but they have not yet been tailored for, nor widely implemented in, complex systems designed for long-term protection. Similarly, methods for defining general criteria for these parameters are fairly well developed, but site-specific criteria using the Data Quality Objective (DQO) process defined by the EPA have not been effectively deployed for complex systems. Methods are needed for identifying, prioritizing, optimizing, and selecting risk-driving parameters and surrogates to be monitored, such as moisture flux from covers and outflow rate from reactive barriers.

Integration into CC&C Monitoring Systems of Leading Indicators for Containment Performance or Failure. Indicators are needed that ensure that individual components of CC&C systems, such as the barrier, collection, and treatment components, as well as whole systems, are operating within expected performance envelopes. Currently used indicators—for example, monitoring at the "point of compliance"—detect changes in performance "downstream" (down-gradient) of the CC&C system after a failure occurs. Early warnings—such as precursors of changes in system performance prior to containment failure—are needed so that effective action can be undertaken long before a failure occurs. To achieve effective, efficient CC&C for the long term, chemical, geophysical, and biological indicators that provide early warning must be identified and integrated into the performance monitoring plan during the design and construction phases of new systems or the maintenance and upgrade cycles of older systems.

Methods and tools for identifying short-term performance and failure indicators are reasonably well developed (e.g., for solid and municipal waste landfills and mill tailings cells). They are not well developed for complex systems and have not yet been deployed to indicate performance and failure reliably over the long term.

Spatial and Temporal Optimization of Monitoring Networks. A capability for optimizing monitoring networks can be implemented as a set of tools, principally software tools. These tools will enable a site steward to decide where and how often measurements or samples should be taken to determine whether (a) conditions have changed, (b) risks have increased, or (c) the remedial system is operating properly. The monitoring networks to be optimized will generally include physical, chemical, and biological measurements in, or samples taken from, the subsurface, the surface, and the atmosphere.

Uncertainties in conceptual models, key parameters controlling important fluxes, and forcing functions will require a statistically based monitoring network. The monitoring network will be characterized by (1) the zone of influence (support) of the sensors or sampling devices, (2) the spacing between sensors, and (3) the extent of the domain or site to be monitored. Initial applications will require separate optimization tools for each pathway (air, surface, and subsurface) because models and approaches that treat coupled systems realistically are currently limited. As research proceeds, a coordinated monitoring approach will become feasible and should be pursued.

The roadmap team estimated that optimization of monitoring networks in this way will have high impacts for reducing cost, reducing risk, and reducing uncertainty. The capability to reduce monitoring points and frequency while retaining the critical information needed for site performance assessment and monitoring of specific engineered containment and control elements will greatly reduce life cycle costs. Technical uncertainty will be reduced because the error bands on key performance outputs can be reduced by a factor of 2 to 5 with optimization of the monitoring system. Health and environmental risks will be reduced by a system optimized to provide the critical information needed for early warning of containment failure or contaminant movement.

Design and Emplacement of Monitoring Subsystems/Networks. This area covers the design and emplacement methodology associated with selection and tailoring of contaminant monitoring subsystems, including the selection of appropriate surrogates and indicators (see Capability 4.1 and Targets 4.1a and 4.1b). The design and emplacement techniques should build on the multimedia monitoring framework for the site, through which sensor technology needs are identified (see System Capability 5). The network optimization tools described in the preceding paragraph would then be applied to design an optimized network.[RK9]

Integration of Field Tests, Analogues, and Models in Performance Assessment and Feedback for Continuous System Improvement. The objective of CC&C systems at stewardship sites is to sustain protection over the long term. Thus, iterative performance assessments are needed to integrate ongoing field tests and analogues of system performance with predictive models. The process must also ensure that the resulting assessment information is fed back to the processes for revalidation and re-evaluation, to guide appropriate modifications. Evaluation methods for field testing are well developed, as are general predictive models for performance assessment.

However, observations of installed systems are not being widely recorded and shared in an organized, consistent manner. Natural analogues are not yet well represented in system performance assessments; methods for adaptive updating are not well developed; and results are not widely deployed for feedback to effective procedures to improve CC&C systems or monitoring systems.

The roadmap team integrated S&T work in all eight of the above areas in the following three S&T targets for 2008:

2008 Target for Capability 8.1 (Target 8.1a): For the LTS Technology Store, provide a suite of techniques and technologies (e.g., models, natural analogues, guidance, performance indicators, failure criteria, etc.) to improve planning, decision making, design, monitoring, maintenance, and interpretation of monitoring data at and around CC&C systems.

2008 Target for Capability 8.1 (Target 8.1b): Eighty percent of DOE sites going to closure and stewardship use a monitoring system optimization strategy provided through the LTS Technology Store. [RK10]

2008 Target for Capability 8.1 (Target 8.1c): All DOE sites in stewardship or going to closure and stewardship are planning to use contaminant surrogates and/or indicators in their LTS monitoring systems. [RK11]

Capability 8.2. Validate performance of CC&C and monitoring subsystems

[RK12]As noted in the introduction to System Capability 8, an initial validation of the CC&C units and their associated monitoring networks is required after installation to ensure that all components are performing as designed. This initial validation should be open and well documented, including dissemination of results through the public access portion of the IV&D system (System Capability 6), to assure the public and regulators that the systems are performing as promised. Performance of components and subsystems should be subsequently revalidated on a published schedule, again with the results available through the dissemination capability of the IV&D system. As noted in Section 2.4.1, the technical capability to validate component and subsystem performance can often be designed into the monitoring and data collection elements of the IV&D system.

2008 Target for Capability 8.2: Provide tools through the LTS Technology Store to validate CC&C system and contamination monitoring system performance. [RK13]

Capability 8.3. Validate overall (technical and nontechnical) performance of safety systems and land-use controls

System Capability 9 describes land-use controls and their relation to other stewardship subsystems. The roadmap team anticipates that the LTS planner or manager will choose among several qualified vendors for components of safety systems and their monitoring subsystems. These components might include barriers, signs, sensors, and data display devices. If the key performance metrics for proposed components or subsystems are equal, vendor selection would be based upon issues of availability, fit, configuration, etc. The science and technology role for DOE will be to provide applications engineering in prescribing the specifications and the adaptation of systems that are already performing in the commercial sector and applying them to the environments and specific needs associated with a closure site.

System performance validation can be built into the software components of many site information subsystems (see Section 2.4.1, System Capability 6). For example, from time to time, remote and wireless sensors must be manually challenged with a diffusion injection of known material concentrations to verify all of their design reliability requirements, such as repeatability, precision, accuracy, and sensitivity. These components and others in an integrated safety system will be driven by a data integrator subsystem. Functional requirements for these challenge tests and for other maintenance and repair schedules based on predictive fault methodologies (e.g., mean time to failure, control charting) can be incorporated into the data integrator.

This approach to validation will provide reasonable, cost effective schedules for manual checks or inspections of subsystems and components. The frequency and types of performance checks to be made can be tailored and built on incremental reliability analysis –all entered into the site's IV&D database (Capability 6.1). Manual checks and tests will always be required, but they can be reduced considerably as reliability history builds. As an example, the Fernald site is currently using a software package for predictive maintenance called TabWare, which thus far has proven adequate in optimizing maintenance surety with cost efficiency.

A reassessment tool to aid in periodic re-evaluations can be included in the LTS Technology Store. This module could include, for example, the following techniques and technologies:

46. A decision analysis module that integrates all SSIC subsystems and components and recommends appropriate action or mitigation needed to ensure continued overall safety system performance.
47. A knowledge management module that disseminates useful SSIC performance information (system status, how well it is performing against plan, and flags for any issues that may need resolution) to stewards, regulators, and other stakeholders

2008 Target for Capability 8.3: Provide through the LTS Technology Store a model for both validation and periodic re-evaluation of both technical and nontechnical aspects of safety system effectiveness. [RK14]

Capability 8.4. System performance module for collection, analysis, evaluation, and dissemination of data

Data on performance of the CC&C, monitoring, safety, and access control subsystems will need to be collected, analyzed, evaluated, and disseminated for purposes such as personnel safety, response actions required of site stewards, and system maintainability and continuous improvement. A risk-based approach should be applied to determining the amount, types, frequency and location of sampling or monitoring. The risk assessment required for this approach will be based on a comprehensive characterization of the residual contaminants at the site, the targets selected for monitoring, and the physical and demographic characteristics of each controlled-access area at end state for the site. The roadmap team estimated that 60 percent of the sampling can be performed remotely, with little or no labor required for routine sampling once the system is established.

2008 Target for Capability 8.4: Issue action criteria for collecting, analyzing, and evaluating representative data for security and exposure systems functionality to reduce cost by 60 percent.

Capability 8.5. Periodically revisit cleanup/stewardship decisions to ensure continuous improvement

All the larger DOE sites (e.g., Rocky Flats, Fernald, or Savannah River) contain within them numerous smaller "waste sites" or "site portions" (a waste-contaminated area that is treated by regulators as a single entity for purposes of contaminant characterization and environmental remediation action).[1] Although the permissible land uses (and supporting end states) that will drive long-term stewardship requirements for a whole site will ultimately be defined at fairly large spatial scales, many end-state determinations are currently being made at the level of individual site portions or waste sites. At many whole sites, stewardship is being phased in as cleanup of individual site portions is completed in serial fashion (DOE 2001). Even when a determination has been made for "no further action" at site portions, following risk-based corrective action, the nature of the supporting long-term stewardship requirements often remains unclear (DOE 2001). Thus the relevance for long-term stewardship of the end state that drove the prior corrective action is uncertain.

Inevitably, the appropriateness of end-state determinations, which may have been made on an interim basis, will be revisited—perhaps repeatedly—as the details of site-wide long-term stewardship requirements develop (NRC 2000). At present, however, no clear legal or administrative process exists for such reconsideration. Section ___ of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA), provides for five-year post-closure reviews. But the process of deciding appropriate action at these reviews could easily prove to be one of negotiation with multiple regulatory parties, given the Federal Facility Agreements that guide cleanup actions at many DOE sites. Reconsideration of end states is but one of many possible paths the negotiation process could take.

Reconsideration of end states in the context of the land-use aspirations of the communities surrounding DOE can result in situations where scientific and technical evaluations and

[1] Site portions are defined as "geographically contiguous and distinct areas for which cleanup, disposal, or stabilization has been completed or is expected to be completed … and where residual contamination remains" (DOE 2000).

information are seemingly set in opposition to community and other stakeholder values. The analytic-deliberative process (NRC 1996) has been much discussed as a way of conducting risk-based evaluations in a participatory and productive way. A decision process using an analytic-deliberative approach could provide a practical basis for reconsidering end states at DOE sites. However, the use to date of analytic-deliberative procedures at DOE sites has been imperfect, with inconclusive results despite considerable effort by parties on all sides (Kinney and Leschine, 2002).

2008 Target for Capability 8.5: Ensure continuous monitoring and improvement of LTS and cleanup decisions. Improve stakeholder support. Reduce life-cycle costs.

2.5.2 System Capability 9. Land-Use Controls and Their Survivability

Physical and land-use controls (hereafter, land-use controls) are the systems put in place to ban or restrict human access to or use of resources with residual contamination. The term includes institutional controls (mechanisms that have a legal basis such as deed restrictions, zoning, permit programs), barriers (fences and gates), and notification or education systems (e.g., signs, public awareness programs, fish consumption advisories, museums). Legal restrictions vis-à-vis various institutional controls are designed to prevent unnecessary exposure of humans to contaminants or release of contaminants from containment through human activity. Institutional controls are a regulatory mechanism. They provide the site steward with a number of tools to keep physical barriers in place and effective over time.

Land-use controls will vary dependent on the severity of potential harm and the ease of access to the site. Restrictions, such as zoning or deed restrictions, are the easiest to implement, but effective capabilities may vary greatly. Other restrictions that may be used include reversionary interest, deed notices, tax notices, easements, and servitudes.

Survivability of Land-Use Controls. All sites with residual contamination will rely on land-use controls to limit use of or access to the contaminated resources on the site for as long as the site contaminants pose a potential risk. The literature on land-use controls, as well as common sense, indicates that there is a high probability that these controls will fail over time because of human error, loss of information, or loss of interest in maintaining them. The literature is replete with analyses of the limitations of existing forms of control, how they can fail, and examples of how they have failed. The conditions that could forestall those failures need to be understood better and factored into selection and implementation of land-use controls. Thus, studies of land-use control effectiveness and survival over time are part of the effort needed to provide Capability 7.3: Identify and solve problems that can undermine reliability and consistency in LTS institutions.

Land-Use Controls and Containment Systems. Covers and subsurface barriers by themselves are unlikely to provide comprehensive and effective control against outside intrusion. However, physical barriers combined with legal restrictions on land use complement each other and provide enhanced protection to human health and the environment. Land-use controls can be particularly important in maintaining the integrity of CC&C alternatives that use natural processes and natural analogues (see Capability 2.2). Human activities that disrupt features that appear “natural” to an uninformed intruder may release contaminants without the intruder being aware of the danger.

Land-Use Controls and Monitoring Systems. One of the S&T targets for Capability 5.2 (sensor technology to meet contaminant monitoring needs) is that in 30 years 50 percent of the sensors will still meet their performance standards. Capability 5.2 is also intended to reduce the need for invasive monitoring techniques. Survivable land-use controls are necessary to ensure that these monitoring technologies remain in place for the intended period of performance. Without effective, survivable land-use controls, the investment in remote sensor arrays and technologies may be at risk. Knowledge of the instrumentation, its location, the monitoring capabilities, and the data generated may be lost because of the inability to transfer that information to the current site steward manager, successor stewards, or governmental authorities. Land-use controls must also provide for appropriate access to repair, replace, add to, or remove sensors and other monitoring hardware at a stewardship site.

Capability 9.1. Legal pathway modules to identify potential legal strategies, assess established agreements, and develop draft alternative legal instruments

Transferring cleanup sites to other parties as the long-term stewards is a fundamental DOE goal. Yet, having another party accept even partial responsibility for managing a site with residual contamination remains a major stumbling block for the LTS Program. Major issues have included liability concerns, determination of end state, and cost. The cost issues concern provision for funding site operations and maintenance, contingencies (i.e., unexpected problems), data management, and other continuing costs of stewardship.

While the issues surrounding site transfer are complex and often have site-unique aspects, a reasonably small number of generic strategies for effecting transfer can be developed. Site managers could then adopt and adapt from “potential legal pathways” (referred to here as “pathway modules”) appropriate for their circumstances. Indeed, some standardization of approaches is necessary to avoid endless negotiation at each site with the potential steward(s) about the myriad possible options.

Strategies for ensuring long-term funding of LTS costs are critical to effecting the transfer of sites to non-DOE stewards. No organization will accept full liability or responsibility without some guarantee that funding will be available for operation and maintenance and for contingencies if an unexpected problem occurs (e.g., contaminants begin to migrate and threaten a community at risk).

The legal instruments effecting transfer of LTS sites out of DOE control are also important because they will limit the number and range of LTS activities at a site. For example, transfer agreements should:

48. Implement safety system and institutional control technologies at LTS sites that are tightly focused and directed to be effective and efficient

49. Identify final end-state land uses and corresponding legal instruments to implement only necessary and sufficient technologies
50. Establish front-end legal requirements (current and future) to accompany the end state.

The benefits of developing a useful set of legal instruments, applicable across a range of actual site circumstances, include the following:

51. DOE expenditures and closure costs will be significantly reduced if proven, generic approaches can be applied at multiple sites. The roadmap team estimated cost savings of 50 percent or more on implemented LTS technologies expected by eliminating duplicative closure activities or closure activities that hinder LTS activities.
52. Site closure plans will integrate the S&T options into LTS goals and requirements that can be easily transferred to the post-closure steward(s).
53. Stakeholders will not be taken by surprise.
54. Duplication of efforts between closure activities and LTS activities will be reduced.
55. Dollars and technology development can be focused on agreed-upon LTS end-state needs for safety systems and institutional controls, as well as needs for containment or control of residual contamination and sitewide monitoring.

2008 Target for Capability 4.1: Provide options for potential legal strategies and associated instruments to facilitate handoff of closed sites to final steward(s).

Capability 9.2. Intergenerational archive options for maintaining land-use control information

Land-use controls and survivability of data and information beyond the next few years are primary components to a successful site stewardship system. Inherent in the rapid advance of modern information technology is a high potential for obsolescence of the media on which site information is stored. The passage of time will also bring changes in stewardship responsibility, changes in property ownership on and near the site, changes in cultural norms in the surrounding community and the nation, changes in societal needs, and other changes. All of these changes will contribute to eventual loss of information and data. The degree and speed of that loss is not predictable, but it is inevitable. This inevitability drives the need to preserve essential site information as completely as possible, to ensure continued protection of human health and the environment. To succeed over the long term, the stewardship system must provide information continuity and access, not only for the next few years but also across multiple generations. For sites with residual wastes in containment, ensuring the preservation of data and information is more critical than it is for sites without wastes requiring containment or continued control.

The S&T target for this capability is a companion to the more general target for an intergenerational archive defined for Capability 6.3

2008 Target for Capability 9.2. In the LTS Technology Store options for planning, implementing, and maintaining an intergenerational archive, include tools and capability for maintaining the information needed to keep land-use controls effective. [RK15]

2.5.3 System Capability 10. Integration of Preventive Maintenance Requirements into Site Subsystems

[RK16] Routine maintenance, including periodic inspection, mowing of vegetation, and replacement or repair of components, is a major cost component of long-term stewardship efforts planned for most DOE sites. CC&C measures at these sites include new waste-disposal cells, capped or entombed facilities and contamination zones, and containment of many groundwater plumes. The default technologies for most site closure plans depend on intensive maintenance for their effectiveness, such as frequent mowing and other measures to maintain artificial biological conditions on the site, continuous groundwater pumping and treatment, and frequent repairs to cracked or eroded barrier layers.

Methods for identifying preventive maintenance requirements are somewhat well developed. However, they have not yet been widely deployed to support efficient CC&C systems. Methods for diagnosis and for defining appropriate correction or repair measures are needed. Information on preventive maintenance requirements from existing operations and case histories should be compiled as a starting point.

Optimized protocols for maintenance of cap and cover systems could reduce life-cycle maintenance costs [RK17]by at least $1 million at most DOE sites. Improved understanding of maintenance needs for natural attenuation and reactive barriers could allow similar cost savings on a life-cycle basis. Reductions in health and environmental risks in the event of a future lapse in maintenance activities would be large (thus addressing an area of regulatory and stakeholder concern).[RK18]

2008 Target for System Capability 10: Deploy technologies and protocols that significantly reduce the need for maintenance intervention of installed contamination containment and control systems.

REFERENCES FOR CHAPTER 2

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SUGGESTED HEADINGS FOR CHAPTER 3 SECTION DRAFTS

R. Katt
6/28/02

3.1 2008 S&T Target

Quote the 2008 target here. Don’t worry about starting with the capability statement. Do these draft sections target by target.

3.2 R&D Pathway

The task structure diagram goes here. The rest of the section will “talk through” this diagram” box by box.

If you need to discuss how various tasks (boxes) relate to one another, or what parallel pathways mean, decision points, etc., do it here. Everything after this should be task-specific.

If your 2008 Target represents a metric for developing a capability (“40% of sites use Tool X from the Technology Store”), rather than the outcome of the R&D Pathway, you may want to indicate—here or in the Description or Estimated Duration sections for specific tasks—what will be the key parameters for achieving the metric.

3.3 TASK #1: [Task Title]

Use whatever label goes with the first box in the pathway diagram

3.3.1 Description

Same as in Form B. You can beef it up if you want, but stick to describing this task, not the entire Capability (that should be in Chapter 2). Lots of stuff I’ve seen in Form B writeups is really at the Capability level.

If you have a sequence diagram for the task, put it here, along with any description of the steps in the task.

3.3.2 Current Maturity Level

In addition to giving the color-coding system for maturity, you can put material in here that “supports” the maturity assessment. For example, if WG members have talked with commercial suppliers and they have COTS or near-COTS (stuff they want DOE to help them commercialize) applications, you can talk about them here. Don’t endorse or make judgments about commercial products, just describe them from the standpoint of indicating the maturity of technology that fits the Description you gave under the previous heading.

My personal view is that the maturity level color codes aren’t worth much unless you provide some reason why you’ve assigned that color.

3.3.3 Prerequisites

Same as in Form B

3.3.4 Estimated Duration and Cost

Same as in Form B. I've put the duration and cost together in one heading, because you should be able to provide some explanation/discussion for why the project will take this long, and that discussion will also be relevant to the cost estimate.

3.3.5 Expected Products/Results

Same as Form B

3.4 Task #2 [Title] … Task #n (last Task in Pathway)

repeat as for Task 1 above.

Page: 5
[RK1] Jim M. had a version of this material in the Compiled Draft for the Operation of LTS Systems cross-cut activity (p. 22). I decided it fits better as an illustration of how the Technology Store would be used than as a part of site operations and maintenance. Accordingly, I simplified System Capability 10 to just cover better tools for system maintenance.

Page: 6
[RK2] Note that Capabilities 1.1 and 1.2 have been reversed in this revised draft. In response to my query in the previous draft, Jim C. responded that he thought of [new] Capability 1.1 as providing the [initial] capability to do monitoring and modeling (forecasting) for a site, whereas [new] Capability 1.2 provides the ability to adapt the monitoring and the modeling (forecasting) as our knowledge base improves with time. This strikes me as a worthy distinction between the two capabilities, but not one that was clear in the previous text. I've done some wordsmithing in both sections, **including in the targets**, to try to heighten this distinction. Dave and others need to let us know if this approach is OK with you; we probably should discuss it in one of our conference calls or other venue.

Page: 8
[RK3] Source draft just said "it is estimated that there are…". We need to be explicit about whose estimate this is. I've assumed it's from a DOE document (or DOE contractor report?). Maybe it's from an NRC report?

Page: 12
[RK4] Jim C: I decided to use the original 2008 Target from CC&C 4.1 in the System Performance Validation and Monitoring capability (System Capability 8, specifically Target 8.1a). So I made up a target description here that fits with the capability description and feeds into the old 4.1 target. You'll probably want to reword this in a way that fits your group's Tech Pathway more closely.

Page: 12
[RK5] Dave B. I think this number originated with your M&S group. Do you have a reference for it?

Page: 14
[RK6] Dave B: I've reworded the target to make it viable as a "2008" target. The other option would be to make this a "2010 Target for Capability 4.1" –the only 2010 target we'll have in the roadmap. We'd need to add a comment explaining why this one is different from the rest.

Page: 18
[RK7] I have expanded the material drafted in the M&S group on communications to capture some of the broader issues relevant to SSIC and DMIP perspectives. This gets into that "hard science" stuff that Bill talks about, and it's hard in part because there isn't one simple, technically accepted way to talk about it. But this stuff needs to be said here because it sets the context for System Capability 7, Capability 8.5, and Capability 9.2.

Page: 26
[RK8] The eight areas correspond to pp. 8-11 of the Compiled Chapter 2 draft, namely, CC&C 4.1-2, 4.1-3, 4.1-4, 4.1-5, 4.1-6, 4.1-8; M&S Capability 3.1, M&S Capability 2.3.

Page: 28
[RK9] Dave B. This heading corresponds to the "systemization" aspects of M&S 2.3. The text from M&S 2.3 has already been used in Capability 4.1 and System Capability 5, so I made up some text to refer back to those discussions. Revise/replace as needed.

Page: 29
[RK10] This target is a slight rewording of M&S target 3.1

Page: 29
[RK11] Dave B. I'm not sure how to deal with old M&S target 2.3, which originally was a target for 2010. Is it okay to make it a target that, by 2008, all sites are planning to include surrogates/indicators by 2010? Or do you want to make it a 2010 target that they are all using surrogates/indicators by that year?

Page: 29
[RK12] Dave B and Jim C. I made up this paragraph to provide a lead-in to the S&T target (old M&S 3.1). Is there anything of a more technical nature you want to say about validation procedures or methodology that is needed or that should be used?

Page: 29
[RK13] Jim C and Dave B.: This is a revision of old M&S target 4.3.

Page: 30
[RK14] Jim M. I modified the wording of the target to get in the distinction between revalidation and periodic re-evaluation, as laid out at the top of this section. I think the change remains consistent with your tech pathway to the target.

Page: 35
[RK15] Jim M. This was not an explicit SSIC target before, but it represents a piece of the Intergenerational Archive target. I don't think it represents a major change or addition to the tech pathway.

Page: 35
[RK16] Should this capability become a sixth subcapability under System Capability 8? It seems to fit well with 8.1 through 8.3.

Page: 35
[RK17] Is this cumulative life-cycle cost or annualized life-cycle cost? Is this a work group estimate that we should identify as such? Are we going to provide back up for it in Chapter 3?

Page: 35
[RK18] I don't see how optimizing maintenance protocols reduces the risks resulting from a lapse in performing maintenance in accordance with those protocols. Maybe I don't understand the intended point. Do you by chance mean that optimized maintenance decreases the likelihood of system failure? That's a different point.